CSCI-1200 Computer Science II — Spring 2006
Lecture 16 — Pointers, Arrays, Pointer Arithmetic

Review from Lecture 15

- Standard library sets
- Steps in program design
- Conway's Game of Life

Today's Lecture — Pointers and Arrays

Koenig and Moo, Section 10.1; Malik, pages 742-756

- Pointers
- Arrays, array initialization and string literals
- Arrays and pointers

16.1 Overview

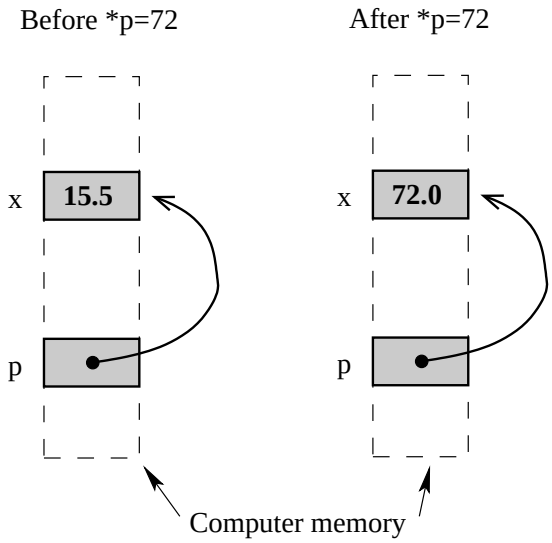
- Pointers store memory addresses
- Pointers are the iterators for arrays
- Pointers are also the primitive mechanism underlying vector iterators, list iterators, and map iterators.
- Dynamic memory is accessed through pointers.

16.2 Pointer Example

- Consider the following code segment:

```
float x = 15.5;
float *p;
p = &x;
*p = 72;
if ( x > 20 )
  cout << "Bigger\n";
else
  cout << "Smaller\n";
```

The output is `Bigger`
because `x == 72.0`. What's going on?



16.3 Pointer Variables and Memory Access

- `x` is an ordinary integer, but `p` is a pointer that can hold the memory address of an integer variable. The difference is explained in the picture above.
- Every variable is attached to a location in memory. This is where the value of that variable is stored. Hence, we draw a picture with the variable name next to a box that represents the memory location.
- Each memory location also has an address, which is itself just an index into the giant array that is the computer memory.
- The value stored in a pointer variable is an address in memory. In this case, the statement:

```
p = &x;
```

Takes the address of `x`'s memory location and stores it (the address) in the memory location associated with `p`.

- Since the value of this address is much less important than the fact that the address is `x`'s memory location, we depict the address with an arrow.
- The statement:

```
*p = 72;
```

  causes the computer to get the memory location stored at `p`, then go to that memory location, and store 72 there. This writes the 72 in `x`'s location.
- The distinction between `p` and `*p` for pointers is just like the distinction between `p` and `*p` for iterators.

16.4 Defining Pointer Variables

- In the example below, `p`, `s` and `t` are all pointer variables (pointers, for short), but `q` is NOT. You need the * before each variable name.

```
int * p, q;
float *s, *t;
```

- There is no initialization of pointer variables in this two-line sequence, so a statement below will cause some form of "memory exception". This means your program will crash!

```
*p = 15;
```

16.5 Operations on Pointers

- The unary operator * in the expression `*p` is the "dereferencing operator". It means "follow the pointer"
- The unary operator & in the expression `&x` means "take the memory address of."
- Pointers can be assigned. This just copies memory addresses as though they were values (which they are). Let's work through the example below. What are the values of `x` and `y` at the end?

```
float x=5, y=9;
float *p = &x, *q = &y;
*p = 17.0;
*q = *p;
q = p;
*q = 13.0;
```

- Assignments of integers or floats to pointers and assignments mixing pointers of different types are illegal. Continuing with the above example:

```
int *r;
r = q;      //  Illegal: different pointer types;
p = 35.1;   //  Illegal: float assigned to a pointer
```

- Comparisons between pointers of the form `if ( p == q )` or `if ( p != q )` are legal and very useful! Less than and greater than comparisons are also allowed. These are useful only when the pointers are to locations within an array.

16.6 Exercise

- What is the output of the following code sequence?

```
int x = 10, y = 15;
int *a = &x;
cout << x << " " << y << endl;
int *b = &y;
*a = x * *b;
cout << x << " " << y << endl;
int *c = b;
*c = 25;
cout << x << " " << y << endl;
```

16.7 Null Pointers

- Pointers that don't (yet) point anywhere useful should be given the value 0, a legal pointer value.
  - Most compilers define NULL to be a special pointer equal to 0.
- Comparing a pointer to 0 is very useful. It can be used to indicate whether or not a pointer has a legal address. (But don't make the mistake of assuming pointers are automatically initialized to 0.) For example,

```
if ( p != 0 )
  cout << *p << endl.
```

  tests to see if `p` is pointing somewhere that appears to be useful before accessing the value stored at that location.
- Dereferencing a null pointer leads to memory exceptions (program crashes).

16.8 Arrays

- Here's a quick example to remind you about how to use an array:

```
const int n = 10;
double a[n];
int i;
for ( i=0; i<n; ++i )
    a[i] = sqrt( double(i) );
```

- Remember: the size of array `a` is fixed at compile time. vectors act like arrays, but they can grow and shrink dynamically in response to the demands of the application.

16.9 Pointers As Array Iterators

- Pointers are the iterators for arrays.
- The array initialization code above, can be rewritten as:

```
const int n = 10;
double a[n];
double *p;
for ( p=a; p<a+n; ++p )
   *p = sqrt( p-a );
```

  Does this look vaguely familiar? It is similar to what you have already seen with vectors and vector iterators.
- But, the assignment:

```
p = a;
```

  is different. It takes the address of the start of the array and assigns it to `p`. This illustrates the important fact that the name of an array is in fact **a pointer to the start of a block of memory**. We will come back to this several times! We could also write this line as:

```
p = &a[0];
```

- The test `p<a+n` checks to see if the value of the pointer (the address) is less than n array locations beyond the start of the array. We could also have used the test `p != a+n`
- By incrementing, `++p`, we make `p` point to the next location in the array.
- In the assignment:

```
*p = sqrt( p-a )
```

  `p-a` is the number of array locations between p and the start. This is an integer. The square root of this value is assigned to `*p`.
- We will draw a picture of this in class.
- Do you see how pointers are just like vector iterators?

16.10 Exercises

For each of the following problems, you may only use pointers (array iterators) and not subscripting:

1. Write code to print the array `a` backwards, using pointers.

2. Write code to print every other value of the array `a`, again using pointers.

3. Write a templated function that checks whether the contents of an array are sorted into increasing order. The function must accept two arguments: a pointer (to the start of the array), and an integer indicating the size of the array.

16.11 Character Arrays and String Literals

- In the line

  ```
  cout << "Hello!" << endl;
  ```

  `"Hello!"` is a *string literal*. It is also an array of characters (with no associate variable name).

- A char array can be initialized as:

  ```
  char h[] = {'H', 'e', 'l', 'l', 'o', '!', '\0'};
  ```

  or as:

  ```
  char h[] = "Hello!";
  ```

  In either case, array `h` has 7 characters, the last one being the null character.

- The C and C++ languages have many functions for manipulating these "C-style strings". We don't study them much anymore because the standard string library is much more logical and easier to use.

- One place we use them is in file names and command-line arguments.

16.12 Conversion Between Standard Strings and C-Style String Literals

- We have been creating standard strings from C-style strings all semester. Here are 2 different examples:

  ```
  string s1( "Hello!" );
  string s2( h );
  ```

  where `h` is as defined above.

- You can obtain the C-style string from a standard string using the member function `c_str`, as in `s.c_str()`.